System Theoretical Research on Language and Communication: The Extended Experimental-Simulative Method

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1 Introduction

The following contribution presents experiences made with a system theoretical methodology within the frame of the Collaborative Research Center *Situated Artificial Communicators* (CRC 360) at Bielefeld University. Starting point for this methodology is, on the one hand, the belief that theoretically and empirically backed research on the complex subject of natural language communication needs a systematic and interdisciplinary integration of methods. On the other hand, this kind of integration is possible only on the basis of a system theoretical conception of linguistics, which combines the predominating structural analytical approach with a procedural analytical approach. The experts from CRC called this a change in paradigms.

The system theoretical idea of a model, which is the basis of the Bielefeld CRC, conceptualizes communication as the interaction of dynamic systems in a given situation using linguistic utterances. The standard empirical setting used in CRC consists of interactions about a construction which are examined and modeled. In these interactions a constructor has to put together the model of an airplane using parts from *Baufix* while relying solely on the verbal instructions of the instructor. In this way we really have a specific system theoretical constellation: the verbal output of the instructor functions as input for the constructor and is processed in dependency on the external situation and the mental state. At the same time the constructor reacts to the input with his own output by making a construction and/or linguistic utterances which are, if necessary, perceived and processed as input by the instructor.

As an example of the explanation of the system theoretical methodology tried out here, the procedure of the partial project *Strategies for the Securing of Understanding* in the CRC was chosen. The subject of examination of this project is the verbal instructions in which the instructor and/or constructor undertake specific linguistic or mental activities in order to arrive at successful communication (coordination of meaning) for the respective construction

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using the verbal instruction. The goal of this project is, for one, the formulation of hypotheses about regularities in the use and linguistic realization of communicational strategies; and secondly, the experimental checking of these hypotheses and their validation in simulation or to make them usable for the construction of artificial communicators.

Which procedure seems most effective in which sequential steps for reaching this goal? In contrast to the usual experimental methodology in psycholinguistics we conducted intensive structure analytical research on the basis of an existing theory of understanding [3, 4] in order to find ecologically valid hypotheses. Consequently, we talk about an *Extended Experimental-Simulative Method.* The first step includes the gathering of an extensive corpus on communication in which the phenomena to be looked at can be observed using manifestly linguistic types of utterances or in which reliable interpretative inferences can be made in regard to this phenomenon on the basis of certain linguistic activities. In the project *Strategies for the Securing of Understanding* we used the option of searching for manifestly verbal strategies for the coordination of meaning. A structure analytical reason for the finding of hypotheses takes place regardless of the specific question according to this principle: it can be ascertained that in the given corpus the output of one interlocutor with the property E1 very often is followed by a second interlocutor's output, which has the property E2. In order to gain a first hypothesis which is formulated as precisely as possible an attempt should be made to find out under what contextual constraints E1 is followed by E2.

Moving beyond the customary approach in conversation or discourse analysis, the structure analytical finding of hypotheses today has the possibility of checking and, if needed, modifying the hypotheses found in the first step using a machine evaluation of corpora. A machine evaluation of corpora needs to be available to annotation as a prerequisite. For this it would be convenient if the respective contextual conditions and features could be identified using formal linguistic indicators.

The use of the comparatively costly experimental methods for checking the hypotheses makes sense only if both structure analytical steps of the examination are used optimally for the formulation of the hypotheses. The specific facts and conditions in an experimental procedure are known from psycholinguistics and need no further explanation here. It should be said that neurolinguistic methods are used increasingly in the Bielefeld CRC. The familiarity of these procedures is due to the fact that in the end transitions between states and reactions in human input-output systems are conditioned neurophysiologically.

It should not be assumed that a single experiment suffices to confirm or falsify the hypothesis to be tested. Very often it cannot be explained sufficiently to what extent the experimentally varying contextual conditions are responsible for the dependency between E1 und E2. Furthermore, there are indications that there are other still unconsidered relevant factors. In such

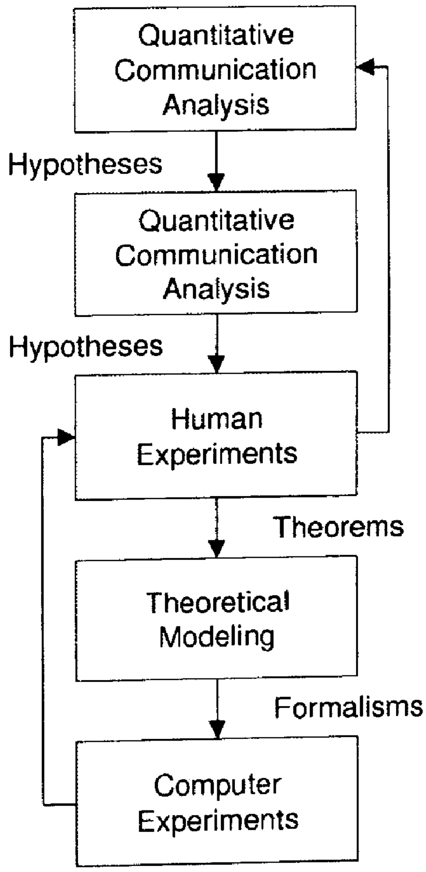

Fig. 1. The flow-chart of the extended experimental-simulative method.

cases it can be useful to modify the hypotheses accordingly and check them again corpus-linguistically before conducting the next experiments.

The experimentally confirmed hypotheses are used in the next step, possibly also using the already available theories on the system interaction to be examined, in order to construct a theoretical model for the system behavior in question. Generally it can be assumed that not all relevant influential factors from the corpus or the experiments conducted are included or controlled. Therefore, very often certain theoretically and/or empirically founded intervening variables are added to the model building in order to arrive at an explanation of wider scope. This allows for a generalization of the validity of the model drafted in contrast to the setting within the corpus and the experiments as well as to certain contexts with differing situational conditions. Of special interest, but also problematic, are the assumptions about intervening variables in respect to the inner states of the systems and their changes.

The final step in the systematic development of a theory is the simulation. It checks whether the laws and assumed conditional constellations underlying the model constructed are sufficient for an explicit and formal modeling of the empirically established system behavior or whether the hypotheses have to be made more precise and explicit.

2 Qualitative Communication Analysis

Research in conversation analysis has shown that successful communication between people relies to a great extent on the interactive coordination of meaning. In this respect it is necessary that the participants in communication know the interactive communicative strategies used in order for successful communication to be modeled. Usually, linguistic discourse research deals with corpora consisting of spontaneous speech. Such corpora have the disadvantage that the communication in these corpora is inhomogeneous in regard to several points: The underlying tasks for interaction and the related communicative expectancies vary and the parts taken over by the communication partners can therefore be defined very differently, meaning that different topics are addressed, etc. In order to allow for a higher comparability and a better generalization of the results of the analysis, it would be useful to work with experimentally elicited corpora. The aspects to be looked at in the communicative behavior can be considered natural in these corpora as well. Therefore, it can be assumed that the observed interaction for the *Baufix*-construction in the CRC-corpus in no way deviates from a "natural" way of behaving. At the same time this corpus serves as a good data basis for the question posed in the project *Strategies for the Securing of Understanding* because instruction dialogues call for a higher level of understanding. This again leads to numerous side sequences with a coordination of meaning. The twenty-two dialogues in the CRC-corpus were transcribed using a relatively easy transcription system and then analyzed for communication problems and their solution using a classification system which was developed in the project. Within the framework of this system it was checked among other things to see whether the participants consider the respective communication problem to be a difficulty in formulating or understanding, and which grammatical form of a sentence is used to solve the problem (e.g. a suggestion in the form of a statement or question), and whether several alternatives for solving the problem are offered, etc. This type of analysis inevitably shows circumstances that occur more frequently or, in the best case, even certain dependencies which form the starting point for the formulation of hypotheses. The constructor in the CRC-corpus, for example, very often uses an inference introduced by the conclusive conjunction *so* (*also* in German) resorting to what he has understood as a strategy and in this way testing the instructor and the degree of success in understanding. Also striking was the fact that questions for clarification from the constructor were usually formulated as alternative questions (using the conjunction *or*) or in form of *wh*-questions (using the question pronoun *which*). This condition suggested checking which type of question depends on what factors. Relatively soon it became clear that the number of referential objects for a suitable interpretation of an utterance is a relevant independent variable.

3 Quantitative Communications Analysis: Computer Assisted Analysis of Linguistic Corpora

The computer assisted analysis of linguistic data uses an annotated corpus of linguistic data as its search space. The core of this data is a transcription of the observed verbal behavior or speech. This information is enriched by additional information which characterizes selections of the verbal behavior in a purpose dependent way. An unlimited number of annotations can be attached to a stretch of speech. The analysis combines search facilities for both the core data and the annotations. In regard to the first, a full text search with regular expressions is used in our system. It is more powerful than a string search since a regular expression describes not only a single string but a set of strings. In regard to the second, annotations assign a finite number of properties to a selection of verbal behavior. The kind of information covered in an annotation is the central property and other properties are assign by attribute-value-pairs, where the attribute subspecifies the aspect of the information given by its value.

In the framework of this CRC 360 we looked at how interlocutors can ensure that they understand one another. They can do so either in a prospective way when they (try to) make sure that no problem arises, or they can do so in a retrospective way when they already have a problem. In construction dialogues where an instructor tells a constructor how to manipulate certain objects, a basic problem is to make sure that both talk about the same objects. In case of an object identification problem due to a lack of information on the side of one of the interlocutors this can be tried to be solved with a request for clarification. Several strategies can be applied in such a case, but, based on eclectic analyses, we were able to formulate an initial set of hypotheses. For their formulation we use the following terminology:

> Depending on the situation, a *specific* or an *unspecific* request for clarification can be formulated. Specific requests for clarification can be a *proposal* (a possible partial object description adding more information to the information already available) or a *list* of two proposals connected with *or*. Unspecific requests for clarification do not name a certain possibility. They are *open questions*, preferably in form of wh-questions.

Hypothesis 1 *The relevant situational parameter is the number of possible reference objects: in case of exactly two objects an or-question is used while a wh-question is used for more than two possibilities.*

This set of hypotheses then claims that the constructor's request for clarification in regard to an underspecified object specification is along the lines of C1, C2, or C3:

I: *take a long bolt*
C1: *the red one?*
C2: *the red one or the yellow one?*
C3: *what colour?*

In order to validate this hypothesis in the corpus one can, in a first step, apply a full text string search for the word *or* in order to identify all possible specific requests for clarification and annotate those occurrences which really are such cases. A full text regular expression search for wh-words (they are actually "*w*"-words only in German and occur in inflected forms as e.g. "*welcher, welche, welches*") will find all occurrences of these words and allow for the classification of those which are really unspecific requests for clarification. Proposals like C1 can not be searched for and have thus to be annotated the hard way. Simple search thus helps find candidates for expressions of a special kind and annotate them accordingly.

Once annotated, one can then search for annotated selections of speech:

- Show all specific requests for clarification
- Show all proposals
- Show all open questions asking for "size««/"color««/"length«« information

Moreover, Boolean combinations of search patterns of the kinds mentioned can be used.

Table 1. The distribution of specific requests for clarification in relation to the number of possible objects.

Number of Possibilities	All requests	C1 cases				C2 cases		
	Abs.	%	abs	% of		abs	% of	
				All requests	All proposals		All requests	All lists
One	126	28	101	**80**	34	3	2	6
Two	193	42	128	66	43	32	17	**65**
More	129	28	67	52	22	14	11	29
Sum	458		300			49		

Table 1 shows some simple results of the numerical analysis. Eighty percent of all requests for clarification found in situations with only one possible object are proposals. This is a significantly higher percentage than that of all proposals. Lists with *or* are the preferred way of formulating requests for clarification in situations with two possible objects (65%). The percentage with respect to all requests is relatively small (17%), but it is significantly higher (Chi^2 = 6,99) than the percentage with respect to all requests. The relatively small number of lists is possible due to the relatively high planning activity needed to produce them. These results are completely in line with the hypotheses formulated above.

The annotation as to form and strategy of a request for clarification is only the starting point for a more detailed analysis, cf. Rittgeroth et al. [8].

4 Human Experiments

As a crucial part of the *Extended Experimental-Simulative Method*, experiments fulfill several important research functions:

- They serve as a *link* between *Quantitative and Qualitative Communication Analysis* and the *Theoretical Modeling* part of the method.
- They clarify the *relationships* between the various variables involved in the research design.
- They give valuable insight into the *mental processes* underlying the observable behavior of the subjects.
  For a detailed discussion of these research functions see section 7.

In order to illustrate these functions of the experimental component we will describe an experiment carried out as part of a larger research project (cf. Kindt et al. [5]). Specifically in the present study we focussed on the influence of referential ambiguity and time pressure on question strategies. Our hypotheses based on the theoretical approach of situated understanding (e.g. [3, 4]) included in addition to the effects of a semantic factor (see Hypothesis 1 above) also a pragmatic factor:

Hypothesis 2 *Time pressure has a significant influence on the question strategy: The instruction to react as fast as possible results in more specific descriptions than no such instruction.*

The experimental procedure consists of a game of cards between two persons: an experimental confident and a subject without knowledge about the experiment. The cards show arrays of four objects, which can be combined in groups of two or three objects, e.g. two large hexagonal bolts, one small hexagonal bolt, and one small round bolt (see Figure 1). On each trial the confident names a specific object in the array which the subject has to identify. If the confident says "the small bolt", there are only two alternative target objects. However, if the confident says "the hexagonal bolt", there are three alternative target objects. If the subject is not sure about the object intended, she or he is encouraged to ask a question for clarification. The type of these questions for clarification is the dependent variable in the experiment.

The whole experimental procedure was tape recorded. In addition, the experimenter documented potentially relevant behavior of the subject.

The results were in line with the two hypotheses given above (cf. Table 1). A referential field of two objects resulted in more specific questions (e.g.

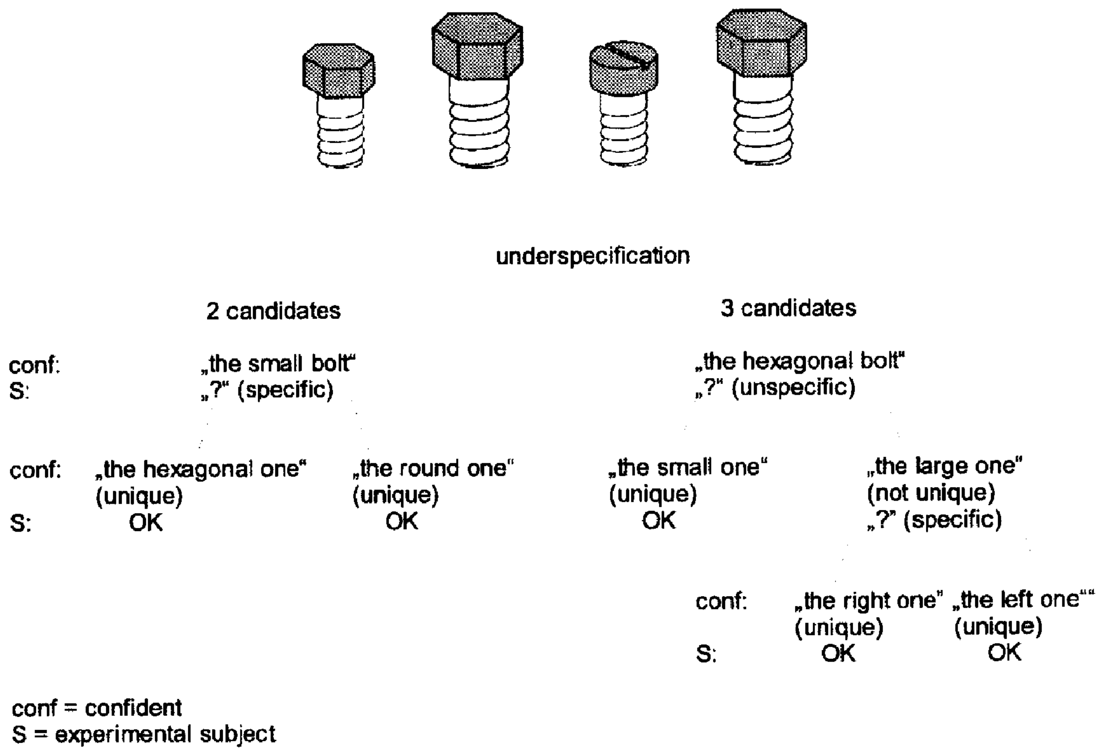

Fig. 2. An experimental situation.

"Do you mean the hexagonal or the round one?") than did a referential field of three objects. In this case, for instance, a preferred question was "Which one do you mean?" Equally, time pressure resulted in more specific questions. These main results of the experiment with human subjects can be transformed into theorems which might serve as an input for the theoretical modeling component of the method.

These theorems are also compatible with the results of *Communication Analysis* of authentic questions for clarification in task-oriented dialogues. Even in cases in which the results obtained from the observation seem to be in conflict with the results from the experiment, a more finely grained analysis was able to show the relevance of the experimentally demonstrated strategies.

Table 2. Main results in absolute and relative numbers of question types.

time pressure	alternatives	specific	unspecific	others	sum
no	2	105 (50,0%)	64 (30,5%)	41 (19,5%)	210 (100%)
	3	98 (42,1%)	93 (39,9%)	42 (18,0%)	233 (100%)
yes	2	119 (63,3%)	48 (25,5%)	21 (11,2%)	188 (100%)
	3	124 (55,1%)	71 (31,6%)	30 (13,3%)	225 (100%)

5 Theoretical Modeling

The theoretical modeling component is the central link between the human and computer experiment components. A theoretical model integrates the experimentally confirmed theorems into a coherent system, which relates the independent variables to the dependent variables. In most cases this is possible only if certain intervening variables between independent and dependent variables are constructed. These hypothetical instances and their functional relations form the creative part of the model and often give reason for critical discussions.

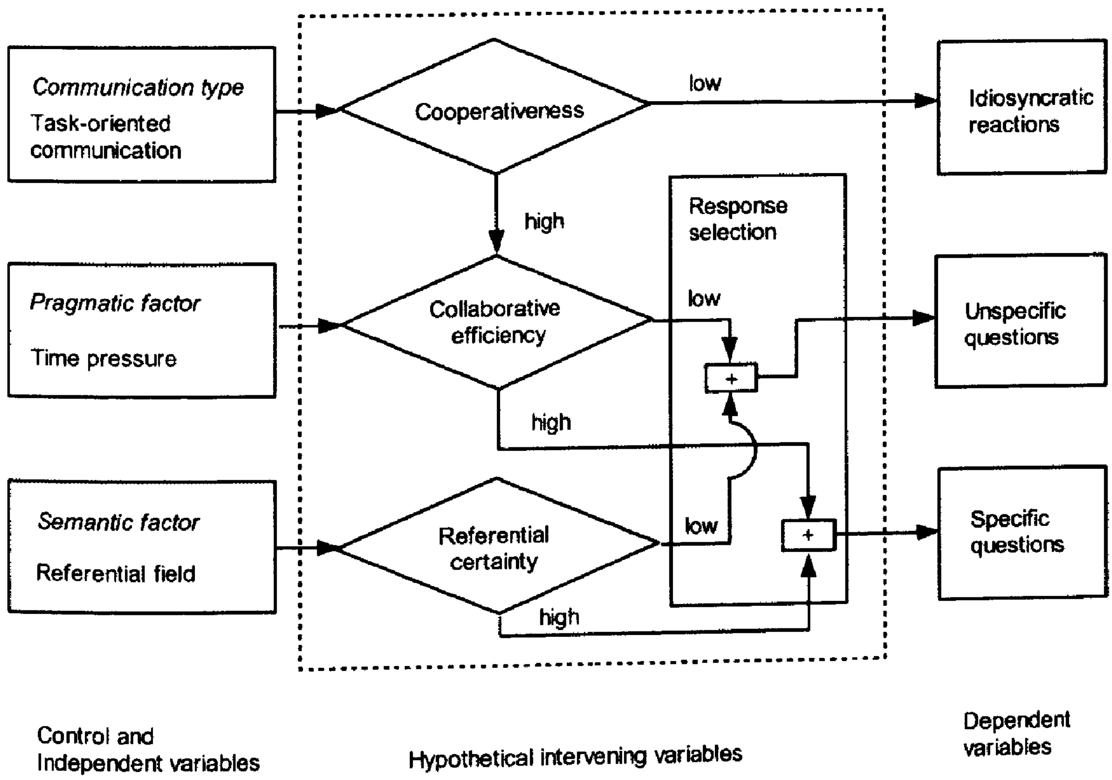

Fig. 3. A simple model of the observed question strategies with its independent, intervening, and dependent variables and its main activation routes.

In order to illustrate the theoretical modeling component we present a simple model of the described scenario for questions for clarification. The model is based on the two theorems which are the main results from the experiment with human subjects. In addition, the fact that there was no tendency towards an interaction between time pressure and referential factors needs consideration. These two significant effects seem to be additive. The model comprises the following four hypothetical intervening variables (cf. Fig. 3):

- *Cooperativeness:* Since a necessary precondition for a successful task-oriented communication is cooperativeness, this intervening variable dominates the whole interaction process. Only if the cooperativeness is high enough, the two independent variables of the experiment can function in a predictable way. Otherwise, the results will be idiosyncratic reactions of the subjects.

- *Collaborative efficiency:* If the subject tries to react cooperatively and there is a moderately high time pressure, the subject should select the most efficient question strategy. Undoubtedly, the most efficient strategy is to ask a question which includes as much information as possible. In this case the cognitive effort may be higher, yet the efficiency of the question will also increase.
- *Referential certainty:* If the referential field consists only of two possible objects, the related knowledge of these two objects and their critical differences should be very good. This referential knowledge is an excellent precondition for planning a specific question, e.g. in the form of "X or Y?« If the referential field consists of three potential objects, the knowledge is more diffuse and the preferred question strategy might be something like "Which one do you mean?"
- *Response selection*: In order to combine the effects of collaborative efficiency and referential knowledge, the model needs an operator for the selection of the response. In figure 3, only the two main important combinations of effects are illustrated. The less important combinations can easily be added to the model.

During the final step of theoretical modeling the described model has to be transformed into a formal system and it has to be implemented as a computer program.

6 Computer Simulation

A model is a reduced and simplified description of a section of reality (cf. Eikmeyer [1]). There is a similar relation between the model and reality. This can be characterized by the fact that the model highlights the essential aspects while it neglects the inessential ones. In addition to this relation the connection between a model and its theory have to be kept in mind. This connection can be better understood through the three levels of description proposed by Marr [6] for information processing models. Such a process takes information as an input and turns it into an output. On the first level a computational theory has to be specified, i.e. a theory which describes what the transition from input to output aims at and why this is suitable. The latter means the specification of the necessary and sufficient conditions of the transformation. These are based on empirical evidence of the process to be described. The second level of description asks for both the representations of the information assigned to the input and the output variables. Moreover, it requires the specification of an algorithm for the transition in the formulation of which the intervening variables play a central role. These two levels can be called the model. Marr's third level, finally, deals with the physical realization of the algorithm. If this realization is done by a computer, it is called a simulation.

The model shown in Fig. 3 is an input-output system, in which the control and independent variables make up the input and the dependent variables make up the output to be specified on the first level. The intervening variables and their connections are used to formulate the algorithm for the transition from input to output. The algorithm is given in an intuitively understandable graphical depiction. A concrete model needs to be more specific, since on the second level representations for both the input and the output have to be specified as well as the details of the algorithm.

Once a model has been specified, it has to be evaluated, i.e. it has to be found out in what respect the model correctly describes reality and in what respect it is false. A computer simulation can be used as a tool for model evaluation. Tests can be repeated almost endlessly, all parameters can be modified and new hypotheses or predictions can be derived.

According to Popper [7] falsifiability is a minimal requirement for scientific models. Marr [6] claims that modeling has to aim at the specification of representations and algorithms. Johnson-Laird [2, p. 52] further adds, that "theories of the mind should be expressed in a form that can be modelled in a computer program".

7 The role of Human experiments in the Extended Experimental-Simulative Method

7.1 The Link Function

Communication Analysis results in a rich description of the communicative processes going on in the intended research field. Usually, this picture gets even more complicated by different results in different case studies. For theoretical modeling the information resulting from *Communication Analysis* is often too complex and too vague. What is needed is an evaluation procedure of the theoretical hypotheses which resulted from the interpretation of the observed behavior sequences. This evaluation procedure is contributed by the experimental method. It includes the following steps.

Hypotheses

Clearly formulated hypotheses are one of the first steps towards theory building. Hypotheses are the result of *Communication Analysis* and a necessary precondition for precise experimentation. Hypotheses are formulated as declarative expressions linking two variable groups of the research topic in the form of 'If group A has property E1, then group B has property E2". Usually, the variable group A is termed the independent variable and B the dependent variable. In order to get the A-B relationship in a relatively undisturbed way other relevant variables C, which may influence it, have to be thoroughly controlled.

Research Design

On the basis of the selected hypotheses the research design spells out the variable types A, B, and C with respect to the experimental setting. If there is more than one variable in the independent group, a factorial design is given. Since in a factorial design the various interactions between the selected variables have to be considered, the number of variables should be restricted to a manageable size. Due to the risk of measurement interferences, the number of dependent variables also should be as low as possible. One of the most difficult experimental tasks consists in controlling the variable group C. If relevant variables are not included in the control, the design may end in an ecologically invalid situation which is not related to the authentic situation observed in *Communication Analysis*.

Interpretation of Results

The interpretation of the experimental results yield answers to the question whether the results contradict the hypotheses or not. In cases in which the hypotheses have to be rejected some interpretation work has to be done. What are the possible reasons for the failure? They may be found in the underlying hypotheses or in the experimental design. A crucial part of the experimental method is to give some tentative answers and, even more important, to give some hints about how these problems can be resolved. The overall criterion for these suggestions is their compatibility not only with the experimental results but also with the observations during *Communication Analysis*.

7.2 The "Causal" Analysis Function

Theoretical models consist of a logically consistent network of propositions. As already mentioned, experimental hypotheses are formulated to fulfill these requirements. The basis of experimental hypotheses is the conditional relation between the independent variables A and the dependent variables B with respect to the controlled variables C. Since the knowledge of conditional relations is a crucial precondition for intervening during the practical application of the theory, the confirmation of conditional relations is a central task for scientific research. Once established, the conditional relation or dependency between variables A and B can be interpreted in a more specific way: Often it raises the suspicion of a causal relation or the person modeling bases the assumption of causality on the neutral dependency relation, thus enhancing the theoretical impact. (Loosely speaking, conditional relations may be termed "causal", keeping in mind that the term "cause" is a philosophical term and is not dealt with in experimental research.)

7.3 The Mental Function

Somewhat similar to the discussion of the term "causal" analysis is the explication of the term "mental" analysis. By trying to explain the confirmed relations between the independent and dependent variables, researchers rely on certain intervening variables. However, the important question is how to interpret these hypothesized structures or processes. Are they believed to be real instances of mental life or do they serve only a formal function in order to connect the input and output of the observed organism? Researchers have to be careful not to fall back onto the ideologically based positions of mentalism or behaviorism. One procedure generally agreed upon in the experimental community is to stick closely to the operationally defined independent and dependent variables. Anyhow, experiments serve as a valid heuristic basis for formulating hypotheses and intelligent and well founded speculations on mental structures and processes.

8 Management of Linguistic Corpora

8.1 Aim and Functionality

The aim was to implement a software system for handling corpora of communicative interactions. From a linguistic point of view this requires the three following basic functionalities:

- *Transcription:* This means the possibility to represent an interaction between two or more persons in a written form. Interactions include both verbal and non-verbal means and that a representation of the language signal produced by the interlocutors is the core of the gathered data. It has to be ensured that arbitrary information can be added to the core data. The visualization of the data uses a score view with a number of voices for the interlocutor's language signal. Such a view easily codes the relation between an interlocutor and what she is saying and, moreover, depicts overlapping speech.
- *Annotation:* This means the possibility of adding meta information to the core data. This type of information is in no way limited with respect to what it is and how many perspectives on the core data it is representing. However, the meta information has to be formally structured to make it treatable by machines. We chose an attribute-value-based approach, i.e. all meta information is represented by attribute-value-pairs, where the attributes to be used have to be specified.
- *Analysis:* All information of the corpus, the language signal and all annotations, has to be accessible for an automatic mechanism which analyzes the data according to the user's requirements. These include full-text search

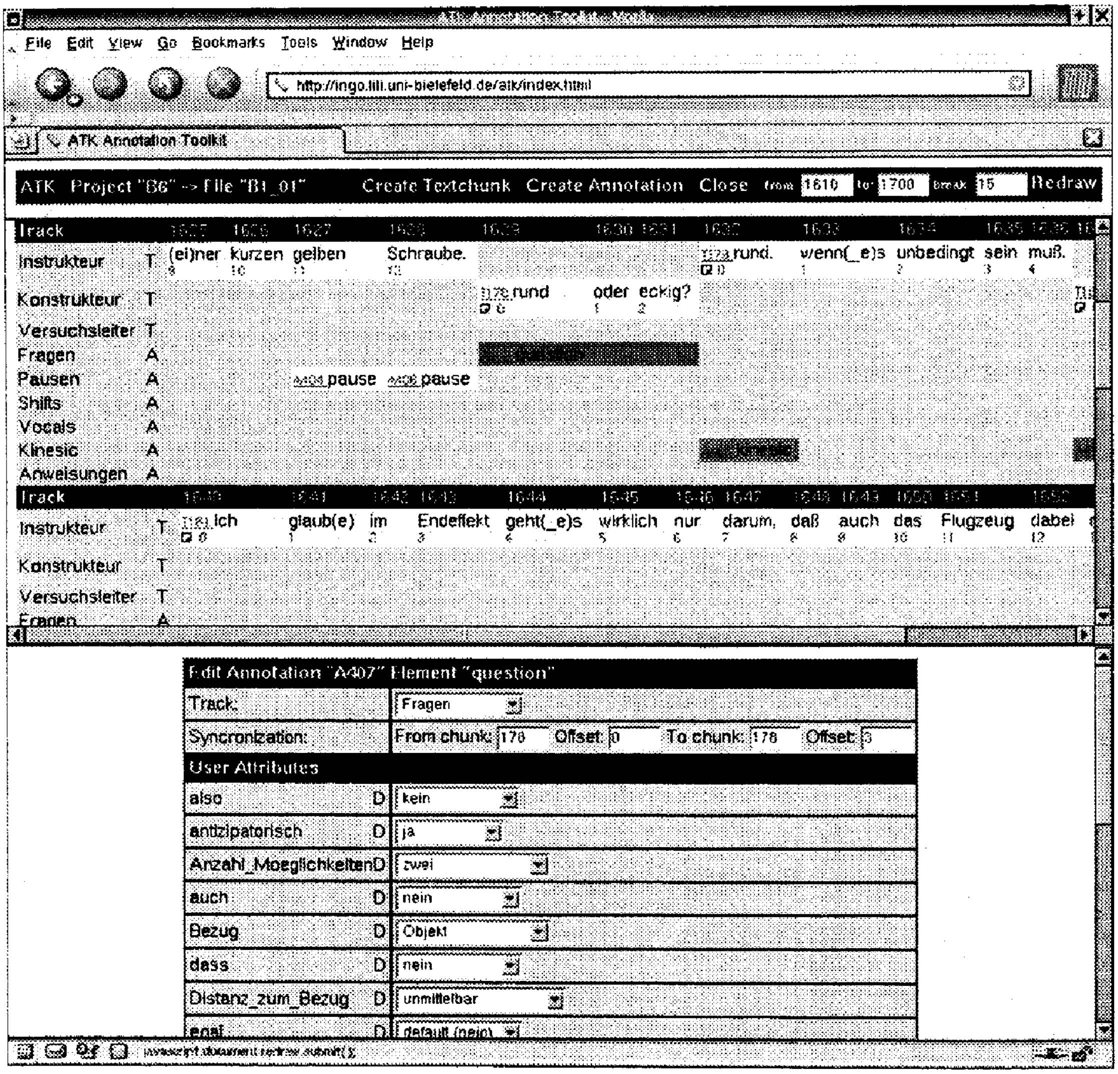

Fig. 4. A screenshot of the annotation tool.

as well as search for attributes, values, or attribute-value-pairs of annotations and combinations of both. All such queries are formulated in a special language.

From a purely practical point of view the two following functionalities were added:

- *Accessibility:* All data has to be easily accessible for a group of several researchers and the system has to be accessible from different places and from any software platform. A web-based approach is optimal for these means.
- *Re-usability:* All information of the annotated corpora has to be exportable in a suitable standardized output format in order to offer an interface to other systems. For practical reasons and based on the current state of the art in text technology we chose XML as our export language.

8.2 Data Model and Technical Aspects

A theoretical data model has to guarantee the formal integrity of the data. We needed a data model for a corpus which is a set of interactions. An interaction is represented by a directed acyclic graph. These graphs contain two types of nodes: those representing a single contribution of a speaker during the interaction – called *text chunks* – and those representing *annotations*.

Text chunks contain an ordered sequence of minimal elements. According to the language transcribed these may be words, morphemes, phonemes, or anything else that might be suitable. All text chunks are related by their respective positions: they start somewhere in another chunk, mostly at its end, but possibly somewhere in the middle. An edge in the graph has this position as the value of its start-attribute. Overlapping speech is thus easily represented.

Annotations are coded similarly: they have two edges pointing to a text chunk and the start- and end-attribute of the respective edges code the relative position of the annotation with respect to the text. Both types of node have a set of attribute-value-pairs attached to them. The set of admissible attributes has to be defined by the user.

Technically, the system uses a client-server architecture. User interaction happens via a web browser communicating with a dedicated web server using the HTTP-protocol. The CGI-interface starts PERL-programs which themselves communicate with a data base (for the persistent storage of the data) and a Prolog-engine (for data analysis). The theoretical data model was mapped onto a relational data base scheme covering both the graph model and the attribute-value based information. In addition to algorithms for data handling, a transformation interface was implemented, which shows the language data in a score view with HTML. A query language was designed for data analysis.

9 Conclusion

The *Extended Experimental-Simulative Method* can be looked at from several perspectives. We will start with a justification for it from a narrower linguistic perspective and then turn to the broader context of cognitive science in general.

The methodology proposed above tries to clarify which significance the methods used for structure- and process-analysis in the different branches of linguistics have for an integrated system-theoretic development of models. These methods are – in contrast to common appreciation and practice – not to be regarded as concurrent but as complementary. Our project was able to show that the analysis of the structure of communication has to combine communication analysis (qualitative and quantitative) with grammarand semantic-theoretical methods. At the same time, the relevance of postulated structures in language and communication can be backed up by process-analytic studies of the systems involved. On the other hand, psycholinguistic experiments might have little impact if they are not based on a differentiated language- and communication-analytical fundament.

The future development of cognitive sciences depends not only on progress in theory construction but also on methodological innovation. We need new methodological concepts and procedures which will contribute to a better integration of the cognitive subdisciplines. This paper presents one possible strategy of relating some of the disciplines to each other. Specifically, we propose that communication analysis, experimental research, and computer simulation cooperate in order to build up a new integrated method named *Extended Experimental-Simulative Method.*

The core of this new approach consists of a close relation between human and machine experiments. The obligatory link between these two types of experiments results from precise theoretical models, which can be formalized in adequate computer programs. If the classic experimental-simulative method is applied to complex discourse, it must be extended. The methods of communication analysis have to be included in order to relate the human experiments to ecologically valid discourse. Since authentic corpora are hard to analyze due to their complexity, computer assisted analysis of these corpora is added to the method.

The *Extended Experimental-Simulative Method* is not only able to contribute to the methodological integration of cognitive sciences but can also form a basis for theoretical progress. If all authors in cognitive sciences could agree that good theories should be transformed into formal models, which are to be confirmed in human and computer experiments, then efficient criteria for theory testing would be available. In our opinion these criteria will be better met by system theoretically derived models than by other types of theory.

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